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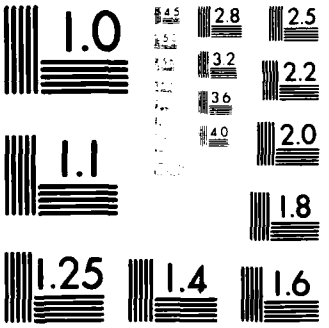

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AUTOMATIC PICTURE TRANSMISSION RECEIVERS FOR WEATHER SATELLITE IMAGES

A BRIEF INTRODUCTION AND SURVEY OF SOME COMMERCIALLY-AVAILABLE EQUIPMENT

by

Peter J. MINNETT

JUNE 1986

NORTH ATLANTIC TREATY ORGANIZATION

SACLANTCEN
LA SPEZIA, ITALY

Published by

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SACLANTCEN MEMORANDUM SM-186

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This memorandum has been prepared within the SACLANTCEN Underwater Research Division as part of Project 23.

R. Thiele

R. THIELE
Division Chief

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Peter J. Minnett

ABSTRACT

The Automatic Picture Transmission (APT) signal is broadcast from several polar-orbiting weather satellites and provides a means of generating images of meteorological and oceanic features in real-time on relatively inexpensive equipment. Following a brief description of the APT signal content, and a discussion of the requirements of an APT receiving station, a number of commercially-available systems are described. A list of manufacturers of APT receiving stations is appended (but it is not intended to be exhaustive).

INTRODUCTION

A brief survey of commercially-available receiving stations for the Automatic Picture Transmission (APT) signals of weather satellites has been made, and the findings are summarized here after a short description of the APT signal content, and a discussion of the desirable characteristics of APT stations.

This document should not be considered definitive as there are likely to be other readily available models, and some of those which have been mentioned may subsequently be replaced by improved versions. It is intended to serve as an introduction to those contemplating using APT data and as an indicator of the types of equipment available. However, as the information has been extracted from manufacturers' brochures it cannot as such be very discriminating: it is no substitute for "hands-on" experience and may not fairly reflect the relative merits of each system.

THE APT SIGNAL

The Automatic Picture Transmission (APT) signal is continuously broadcast from several weather satellites. It can be received by comparatively inexpensive equipment and used to produce broad-swath images of clouds and surface features in real-time. First used in 1963 on the US satellite TIROS-8 (Television and Infrared Observation Satellite) to broadcast images from a television-type sensor, the APT system has undergone develop-

ment with successive generations of satellites and is now used to transmit a subset of the data from the Advanced Very High Resolution Radiometer on the NOAA series of sun-synchronous, near-polar orbiting satellites (sometimes called the TIROS-N satellites after the prototype of the series launched in 1978). These satellites orbit the earth at a height of about 850 km with a period of about 100 minutes; they are deployed in pairs with local times for one satellite of about 0230 and 1430, and for the other of about 0730 and 1930.

The AVHRR is a scanning radiometer with five channels in the visible and infrared parts of the electromagnetic spectrum: 0.58 to 0.68 μm; 0.72 to 1.10 μm; 3.55 to 3.93 μm; 10.3 to 11.3 μm; and 11.5 to 12.5 μm. The last two of these (Channels 4 and 5) are often referred to as the "split-window" channels, since they are placed in an atmospheric "window" (i.e. a spectral region where the atmosphere is relatively transparent). The split-window channels were not present on the earlier versions of the instrument; these had a single channel at 10.5 to 11.5 μm. The noise level in the split-window channels is < 0.1 K. Channel 3 (at about 3.7 μm) has been persistently plagued by noise problems, generally worsening with the age of the instrument, and in the end rendering the Channel 3 data difficult to use for many purposes. The nominal spatial resolution of each channel is 1.1 km at nadir, but because of geometrical effects the resolution degrades to about 4 km towards the edges of the swath.

The data from AVHRR are digital with a resolution of 10 bits. Together with data from other instruments on the satellite and with data from the spacecraft itself, the AVHRR data are continuously transmitted in the High Resolution Picture Transmission format (HRPT) at S-band (about 1.7 GHz) with a bit rate of 665400 bps. Reception of this signal requires a tracking-dish antenna, and, if the data are to be archived, high-speed tape recorders.

A subset of the AVHRR data is converted to analogue form and transmitted as the APT signal at VHF at about 137 MHz, with an equivalent bit rate of 33280 bps. The APT signal consists of two of the five AVHRR channels, but only one scan line in three is processed. The pixels are averaged along each scan line to give a nominal resolution of 4 km, with the averaging interval decreasing towards the edges of the swath to give a first-order correction to the geometrical distortion. Until recently the two APT channels have been the AVHRR Channels 2 and 4, but since the Channel 2 signal consists entirely of reflected solar radiation it is of no use at night. Since about July 1985, Channel 3 data, which include thermally emitted energy, have been substituted for Channel 2 data for the nighttime part of each orbit of NOAA-9.

The APT signal is intended primarily for the generation of images using analogue equipment (e.g. television screens or weather-facsimile printers), but it has been shown that with care the data can be digitized after reception and calibrated to be useful in computer image processing and analysis schemes for more demanding operational requirements or for research purposes (Wannamaker, 1983; 1984).

Fuller descriptions of the HRPT and APT signals, and of the TIROS-N series satellites, are given by Schwalb (1978, 1982).

"METEOR" TRANSMISSIONS

The USSR also operates weather satellites, called the Meteor series, which broadcast images in a similar manner to the APT system. The visible-channel data appear to have a higher spatial resolution than the APT data, but the infrared is apparently of lower quality. Technical information about the satellites and sensors is not available. Nevertheless, some commercial APT receivers offer the capability of "Meteor" data reception.

GEOSTATIONARY SATELLITE DATA

The geostationary meteorological satellites provide another source of imaged data. These satellites orbit the Earth in the equatorial plane and appear to be at a fixed position relative to an earth-bound observer. They include "Meteosat" of ESA (the European Space Agency) above 0°E, and GOES-E and GOES-W (Geostationary Operational Environmental Satellite, East and West) of NOAA, above 75°W and 135°W respectively. The data are transmitted at S-band and can be received by a small (about 1-m diameter) fixed-dish antenna. With a suitable down-converter, APT reception and display systems can be used for geostationary satellite data. A fixed-dish antenna is suitable for land-based reception, but is not suitable for use on a ship unless a stabilized platform is available.

REQUIRED CHARACTERISTICS OF AN APT SYSTEM

It is assumed here that the APT receiver and display system is to be used primarily by a meteorologist or navigator wishing to obtain recent information about local and synoptic-scale weather, or by a sea-going oceanographer wishing to locate surface-temperature fronts. The commercially-available APT systems are unlikely to meet the needs of a remote-sensing oceanographic specialist who would prefer to use digital APT data in a computer (as in the SACLANTCEN receiver and STARS - Satellite Analysis and Research System - software) or, better still, high-resolution data supplied on computer-compatible tape by a ground station receiving HRPT signals.

The APT satellite station consists of an antenna, a receiver, a decoder (which converts the signal from the receiver into a form suitable for display as an image), an image store, and an image display system which generally uses a television monitor. The APT station should at a minimum meet the following requirements:

1. The whole system should be easy to use by a non-specialist and should have clearly-labelled controls and displays. Part of this requirement is a good handbook, i.e. one with clear explanations of the procedures to be followed to optimize the use of the equipment, and a clear "trouble-shooting" section.

2. The system should be designed for high reliability, with easily-available replacement parts and consumables. These replacements are especially important if the system is to be used at sea, possibly without the support of specialist service engineers.

3. The receiver should be stable with good out-of-channel rejection. This feature can be crucial if the equipment is to be used in an electromagnetically noisy environment, such as large cities. In some locations it may be necessary to replace the omnidirectional antenna with a directional one (which then introduces the added complexity of needing to track the satellite across the sky). A small audio loudspeaker is often a useful indicator of when the APT signal is being received successfully.

4. The image display should be clear and stable, and it should be possible to adjust the contrast. (A zoom facility which enlarges a chosen portion of the image is very desirable. The use of a colour monitor is useful, especially if the range of colours can be chosen to emphasize particular features.)

5. The system should be able to store and redisplay pictures in such a manner that successive images can be easily compared.

6. The ability to overlay a grid of annotated latitude and longitude lines is necessary, even though it is generally possible to recognize some parts of coastline somewhere in a given image, and thereby roughly determine the geographic position of features in that image. Without an overlying grid, the geometrical distortion of the image is often so great that geographical positions cannot be determined sufficiently accurately for various purposes, such as: comparing the positions of features in successive images (e.g. cloud motion); identifying features at a known geographical location (e.g. describing the conditions in the vicinity of a ship or buoy); assigning geographical coordinates to a particular feature in the image (e.g. directing a ship to a surface temperature front). (The alternative approach of remapping the satellite image to a standard map projection is presently beyond the capabilities of these APT stations.)

7. The production of a hard-copy replica of the image displayed on the screen, or a part of it. This permits permanent annotation of the image, quick comparison with other images or other data represented in a similar form (e.g. surface-temperature charts) and the possibility of compiling a library of images.

8. A digital output signal to transfer the data to a digital data-logger or transfer a computer for storage on disk or tape (for archiving

or further transfer) prior to digital display and analysis. (A fuller discussion of how this is done at SACLANTCEN is given by Kitchen et al., 1982, and Wannamaker, 1983.)

DISCUSSION

The equipment discussed here is manufactured by Feedback Instruments, Spembly Electronics, Muirhead Data Communications and F.G. Engineering. The addresses of these companies are given in Appendix A. The Muirhead equipment appears to be the combination of a Spembly Electronics antenna with Feedback Instruments electronics.

A summary of some of the relevant characteristics of the equipment is given in Table 1.

The Feedback and Muirhead equipment offer the basic facilities of an APT station with simple controls and adequate displays. However, for some purposes, the limited image-manipulation facilities (zoom and hard-copy) appear to be possible only at the time of reception, and the small number of stored images could be restrictive.

The Spembly station offers much more image processing and ready access to a large number of previous images. The equipment is under microcomputer control and this allows considerable flexibility in data acquisition, such as pre-scheduling the reception of the required satellite transmission. It also allows flexibility in image processing as it includes contrast enhancement, zoom and false-colouring. However, hard-copy output seems possible only at the time of image reception. A small VDU and keypad are used for program selection from a series of menus. This equipment is an intermediate step between the basic Feedback Instruments station and a digital station with the full computerized image display and analysis facilities of a system such as that at SACLANTCEN. The Spembly Electronics station is in use with the UK Royal Navy.

The FG Engineering equipment is highly modular and very flexible, with the capability of receiving not only APT data and the S-band (WEFAX) signals from the geostationary satellites, but also transmissions from TIP (TIROS Information Processor), DCS (Data Collection System), HRPT and VISSR (Visible and Infrared Spin-Scan Radiometer).

The TIP signal contains data from the low-bit rate instruments on the TIROS-N series of satellites (i.e. non-AVHRR data); the instrumentation includes radiometers for measuring atmospheric temperature and humidity profiles and, on the later satellites, components of the earth radiation budget (see Schwalb, 1982). The DCS (commonly called the ARGOS system) collects environmental data from fixed or moving platforms and can determine the position of the transmitter (e.g. on a buoy). The DCS is part of the payload of the TIROS-N satellite, with

Table 1

Summary of APT station characteristics

	Feedback	Muirhead	Spembly	FG Engineering
Size	22x44x36 cm	22x44x36 cm	-	various
Receiver channels	5 APT	5 APT	-	6*
S-band option	yes	yes	yes	yes
Image display	256x256 pixels 4 bit	256x256 pixels 4 bit	-	640x400 pixels** 4 bit
Image monitor	15" b/w 625 lines, 50 Hz	9" b/w 625 lines, 50 Hz	b/w or colour 625 lines, 50 Hz	IBM PC colour display
Contrast stretch	(yes)***	(yes)***	yes	yes
Zoom	(yes)***	(yes)***	yes	yes
Hard-copy output	yes	yes	yes	yes
Images stored	3	3	200	>> 200
Playback mode	-	-	yes	yes
Lat/long grid	-	-	yes	yes
Digital O/P	yes	yes	yes	yes
Programmable reception	-	-	yes	yes
Defence Standard	UK Standard 05-29	UK Standard 05-29	UK Standard 05-21	-

* Modular construction with considerable flexibility (see text and Table 2).

** The characteristics given at this line and below assume use with an IBM PC.

*** Limited capabilities.

Dashes indicate that the information is not given in the manufacturers' brochures.

its data being part of the TIP transmission. It is also on the US GOES geostationary satellites, along with the VISSR.

The antennae and receivers available from FG Engineering are given in Table 2. Image display facilities do not appear to be part of the equipment made by FG Engineering, but their receivers are incorporated into the systems of other manufacturers, such as Northern Video Graphics Inc. In this configuration up to 12 images can be stored in memory and many more on cassette tape. There is a digital output to a computer. Northern Video Graphics Equipment is used by the US Corps of Engineers, NASA, NOAA, Environment Canada, Telespazio in Rome, and many others. Alternatively, the FG Engineering equipment can be interfaced to an IBM PC, with hardware enhancements and Electro-Services/COMFAX software, for image display and processing; in this way, useful IBM PC capabilities (such as image storage on disc, zoom, false-colouring and hard-copy output to a printer) are available.

Table 2

Antennae and receivers manufactured by FG Engineering

(a)

Antenna Type	Broadcast Signal					
	APT	TIP	HRPT	WEFAX	DCS	VISSR
2.4 m tracking	-	-	P	S	-	-
2 m polar mount	-	-	-	P	-	-
4 m polar mount	-	-	-	S	P	-
7 m polar mount	-	-	-	S	S	P
helical omnidirectional	P	P	-	-	-	-

(b)

Receiver Type	Broadcast Signal					
	APT	TIP	HRPT	WEFAX	DCS	VISSR
FG - 701	-	-	-	P	-	-
FG - 702	P	P	-	-	-	-
FG - 703	-	-	P	-	-	-
FG - 7100	P	P	P	P	-	-
FG - 7200	-	-	-	S	P	P

P = primary usage, S = secondary usage, dashes = not suitable.

SUMMARY

A number of commercially-available APT receiving stations have been briefly described. These range from relatively modest stations with limited capabilities to quite sophisticated and flexible systems offering some of the more straightforward digital image-manipulation facilities that are available on computers equipped with image processing and analysis systems.

Where comparisons have been made, only technical features were considered, i.e. there is no cost comparison. Further details are available from the manufacturers listed in Appendix A.

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WANNAMAKER, B.W. An evaluation of digitized APT data from the TIROS-N/NOAA A-J series of meteorological satellites. International Journal of Remote Sensing 5, 1984: 133-144. (Also: SACLANTCEN SR-78. La Spezia, Italy, SACLANT ASW Research Centre, 1984.)

APPENDIX A

ADDRESSES OF APT RECEIVING STATION MANUFACTURERS

Electro-Services/COMFAX
1455 Lookout Drive
P.O. Box 2214
No. Mankato, MN 56001
USA

Feedback Instruments Ltd.
Park Road
Crowborough
East Sussex TN6 2BR
UK

FG Engineering Co.
Box 476
Fredonia
AZ 86022
USA

Muirhead Data Communications Ltd.
34 Croydon Road
Beckenham
Kent BR3 4BE
UK

Northern Video Graphics Inc.
511 Eleventh Ave. S.
Minneapolis, MN 55415
USA

Spembly Electronics
Hays House
Steeple Drive
Alton
Hampshire GU34 1TN
UK

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